NEWSLETTER 50
Istituto Nazionale di Fisica Nucleare
AUGUST 2018

» INTERVIEW

EINSTEIN TELESCOPE: EUROPE MOVES TOWARDS THE THIRD-GENERATION GRAVITATIONAL-WAVE INTERFEROMETER

Interview with Michele Punturo, INFN coordinator of the project

It is called ET, Einstein Telescope, and represents the new scientific and technological challenge thrown down by Europe for research into gravitational waves. The project envisages the construction of a gigantic underground third-generation interferometer, which is already on the roadmaps of international institutions for scientific and economic development. ET is designed to be sensitive especially at low frequencies and it will enable regular, highly detailed observation of the gravitational waves generated by the coalescence of compact bodies, such as black holes and neutron stars, at cosmological distances, to bring to reality what is called high-precision gravitational wave astronomy. The observatory will be triangle shaped with three arms, each 10 km long, making a total perimeter of around 30 km, and will be positioned at a depth of between 100 and 300 metres, in order to insulate it against seismic waves. At present, the process has begun of submitting applications for sites interested in hosting the future laboratory, which will be one of the leading-edge infrastructures in scientific research worldwide. Italy is one of the candidate Nations, with the Sos Enattos site in Sardinia. We discussed the scientific and technological aspects of the ET project, and Italy's bid to host it in Sardinia, with Michele Punturo, the INFN coordinator of the ET project.

What is it that makes ET a third-generation interferometer? How will it improve research into gravitational waves?

The leap in technology and design brought about by ET will enable an improvement in sensitivity to a factor of 10, with special attention paid to low frequencies close to the Hertz. That corresponds to an observable volume 1000 times greater than second-generation detectors, when they reach their design sensitivity. For black holes, that means being able to see the whole history of the universe,

» INTERVIEW

studying the evolution of the black hole populations and therefore understanding the mechanisms that have led to the formation of the astrophysical bodies seen by LIGO and Virgo. By making detailed observations of thousands of coalescences of neutron stars every year, ET will reveal the mechanisms of nuclear physics at the basis of the existence of these stars, mechanisms that are also being investigated with other instruments at CERN with the LHC. In conjunction with traditional telescopes, in the area of multi-messenger astronomy, ET will be able to verify the cosmological model of the universe and contribute to understanding the enigma of dark matter and dark energy. But ET, with its wide spectral band, will also be an instrument of pure discovery, in other words observation of what we do not know today and that will surprise us.

What are the main challenges to be overcome in order to develop ET?
There are a lot of challenges: technological ones, having to improve by 3 times the performance of the apparatuses making up the current detectors, such as Virgo and LIGO. Those apparatuses represent the cutting-edge technology we have been able to develop so far, and we must now surpass ourselves by introducing new solutions (cryogenics, new materials) and improving existing ones. Engineering challenges: having to build an underground infrastructure, similar to LHC in terms of size, with extremely low levels of environmental noise and ensuring maximum safety for those working there. Scientific challenges: for handling of data and its scientific comprehension we will have to develop new algorithms for analysis, new models of sources and perhaps new theories. Financial and organisational challenges: ET is a pan-European project, worth billions of Euros, which will require the backing and cooperation of several nations and agencies.

What synergies are there with other INFN research sectors, such as, for example, high energy physics.
It is amazing how much synergy there is between the world of gravitational waves and nuclear and high energy physics, both from a scientific and technological point of view. As already mentioned, neutron stars are a nuclear physics laboratory where you can go to study matter in conditions of density that cannot be reached in laboratory settings and which could reveal new states of matter. Using the emission of gravitational waves from black holes (superradiance) or from coalescence of neutron stars can reveal the presence of light bosons or axions, which might help to explain dark matter or the mechanisms of cosmic inflation. Verifying general relativity or the alternative theories of gravity, which can be done with ET, may help to understand the cosmological model of the universe and the role of dark matter. On the other hand, the technologies developed in the world of high energy are vital for ET: cryogenics, ultra-high vacuum chambers of gigantic dimensions, control systems, high-performance electronics, data

» INTERVIEW

acquisition systems, computing. INFN has an incredible abundance of skills in all these fields, which has enabled it to take on a leadership role in high energy physics. ET needs these skills in order for it to be implemented and it will definitely ensure that INFN continues to take the lead, in the future of gravitational waves. The topic of ET synergies is on the agenda of the INFN next town meeting (6,7 September) dedicated to the new roadmap for particle physics.

What are the required features for hosting the infrastructure? Which are the candidate sites for hosting ET?
In this stage of conceptual study, we have carried out inspections at several potential sites and measured seismic and environmental noise. Some have shown to be potentially compatible with the set requirements, linked to low seismic noise, geological stability and low anthropisation. Attention has focused on three sites, in Hungary, in the Netherlands (on the border with Belgium and Germany) and in Italy, at Sos Enattos, in Sardinia.

Why has Italy identified Sos Enattos as the suitable site?
Because it meets the requirements of ET perfectly: Sardinia is extremely stable from a geological point of view and, at the Sos Enattos site, presents an extremely low level of seismic noise. Barbagia is one of the areas of lowest human density in Europe and, since human activity generates seismic noise exceeding a few Hertz, this means the site is extremely silent. The rock that could be excavated to house ET has excellent resilience and is extremely low on water, making it feasible to create the infrastructure. Sardinia also offers outstanding skill in the area of mining, so there is expert labour and know-how locally available.

What advantages are offered by hosting a scientific project like ET?
Research infrastructures act as a driver for cultural, infrastructural and economic development in the areas that host them. ET will bring development, both during its construction and in the operational stage: construction of the ET infrastructure is an activity involving high-intensity work for at least 5 years. Then, once operational, ET will attract scientists, engineers, technicians and administrative staff, to transform an area that is in serious economic hardship. And what is more, this presence will last over time, since gravitational wave observatories, unlike other types of infrastructures, require the presence of large numbers of people and the activities of ET are planned to last several decades. ET needs support infrastructures, such as high-speed internet connections, transport access and housing. It will also stimulate the growth of local business, for support and maintenance activities,

» INTERVIEW

or by virtue of technological spin-off. In particular, ET reconciles two aspects that appear to clash: development and environmental conservation. Indeed, the need for an area of low environmental noise levels will call for restrictions in the area around the interferometer, with careful selection of the type and impact of the new infrastructures.

Which countries are, at the moment, backing the Einstein Telescope?
Italy is at the forefront, thanks to the direct, original contribution of INFN, the support of the Sardinian Universities, above all Sassari, and the interest of the National Institute for Astrophysics (INAF). France is currently making a contribution through the collaboration between the Centre National de la Recherche Scientifique (CNRS) and the INFN in the European Gravitational Observatory (EGO), the consortium that runs Virgo, and that has also acted as coordinator for the study of the ET project. The Netherlands, through Nikhef, is pushing hard for the north-European site, involving some Belgian universities and, in Germany, the Max Planck Institute for Gravitational physics (MPG) and the University of Hannover. The Wigner Institute is sponsoring the site in Hungary. The Scottish and English universities (such as Glasgow, Birmingham and Cardiff) are backing the project heavily. In Spain, renewed interest is currently growing, especially in view of a possible site near the Pyrenees, in Canfranc.

The discovery of gravitational waves and the birth of the new multi-messenger astronomy are among the most promising lines of research for the coming years and Europe is investing in ET and the LISA project for a space interferometer in orbit around the sun. What are the other scientific communities in the world working on?
The pioneering ET project and the discovery of gravitational waves, together with the birth of multi-messenger astronomy, have stimulated the spread of the concept of detectors of third-generation (3G) all over the world. In the United States, the idea of a 3G detector is taking shape with the Cosmic Explorer proposal, a concept design recently financed by the National Science Foundation (NSF). That is why we have set up a global coordination project, called GWIC-3G, to unite and organise global efforts in the science, technology and management of the future network of third-generation observatories. Other players, such as Australia, have also directed their efforts and interest towards this coordination.

The upgrading of the detectors LIGO and Virgo is almost complete and they will soon be back in operation. What work is programmed for the second-generation interferometers and for ET?

» INTERVIEW

There is a good deal of continuity between the activities of Virgo and LIGO and the development of ET and all the other third-generation observatories. There is a coordinated upgrading and data capture plan for existing detectors which, in the next decade, will allow them first to reach their nominal sensitivity and then to go beyond that, with the installation of new technologies. The positive effect will be twofold. Firstly, the technologies installed for upgrading the second-generation detectors often constitute a first step towards the technologies required in ET: this is an excellent means of reducing the risks for ET. Furthermore, in its early years, ET will benefit from the existence of the (improved) second-generation network, working with it to locate the strongest sources, pending completion of the third-generation network. ■